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# Marine observations with a harmonic single-beam echo-sounder

## SEA TECH WEEK 2020

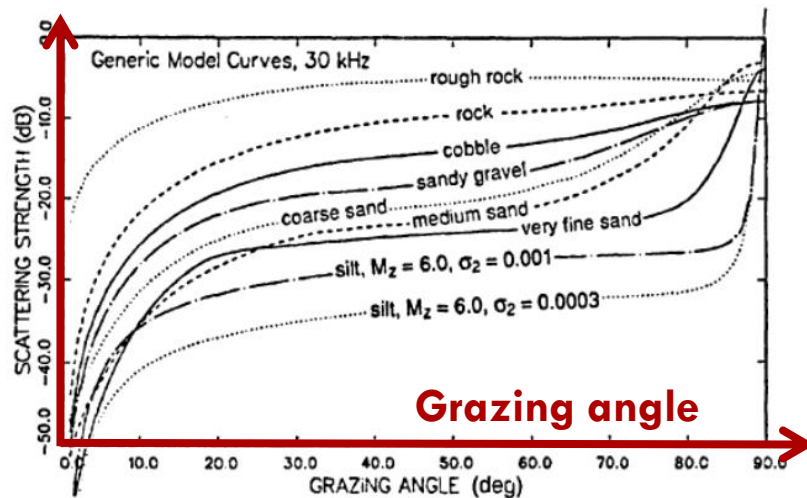
Irène MOPIN, Jacques MARCHAL, Michel LEGRIS, Philippe BLONDEL,  
Benoît ZERR, Gilles LE CHENADEC

# Introduction

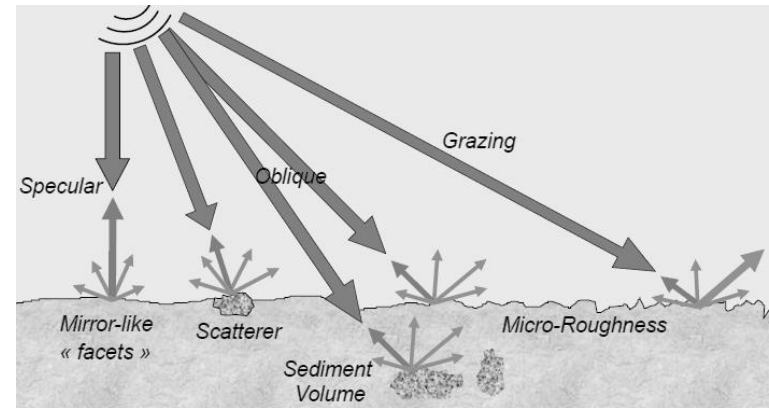
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- Seabed characterisation: reflectivity dependencies =  $BS(f, \theta)$

## Acoustic response of the seabed



Xavier Lurton, Ifremer, GEOHAB Workshop, 2013



Xavier Lurton, Ifremer, GEOHAB Workshop, 2013

- Dependence on frequency and incidence angle
- Limitation: require several echosounders at several frequencies
  - expensive and bulky system

# Introduction

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- Solution suggested: a single echo-sounder using several frequencies
- Goals:
  - ▣ Designing a prototype of echo-sounder (transmitter and receiver) able to generate multiple frequencies simultaneously and acquire their echos.
  - ▣ Analysing results of acquisition on different seabed types (at sea) in order to validate the feasibility of characterising seafloor with this echo-sounder.

# Summary

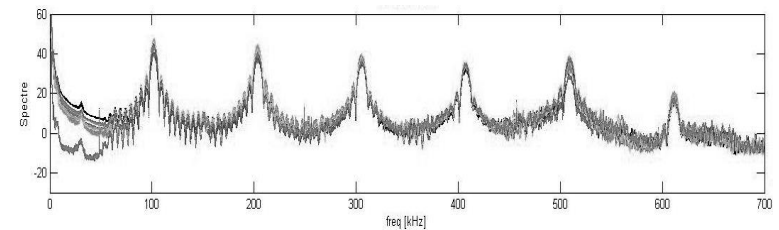
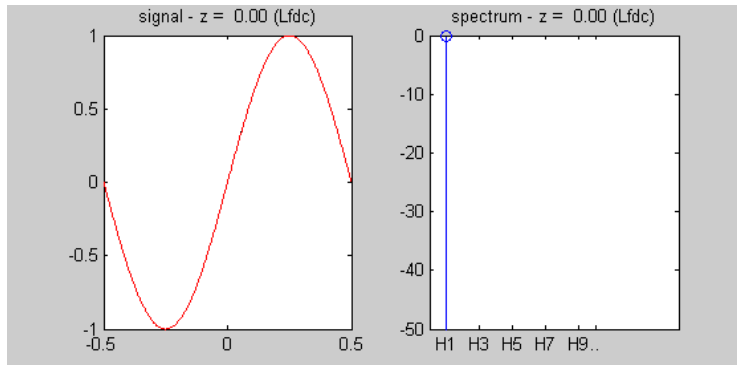
4

- I. Design of the prototype
  - 1. Principle of multiple frequencies generation
  - 2. Transducers design
  - 3. Transmitter functional validation
- II. Data processing method
  - 1. Calculation of the seabed reflectivity index ( $BS$ )
  - 2. Estimation and modelling of  $BS(f, \theta)$  curves
- III. Survey in the bay of Brest
  - 1. Survey description
  - 2. Results
- IV. Conclusion

# Transmission of multiple frequencies

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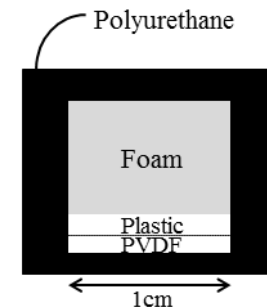
- Generation of harmonics during propagation in the water column



L. Di Marcobardino, J. Marchal and P. Cervenka,  
Nonlinear multifrequency transmitter for seafloor characterization,  
Acta Acustica, 97(2), 202-208, 2011.

➤ Transmission of a single frequency at a high power level => produces harmonics during propagation

- Transmitter: Ø18cm – 100kHz – Piezoelectric composite disk
- Receiver : Ø1cm – Wideband – PVDF + Plastic + Syntactic foam

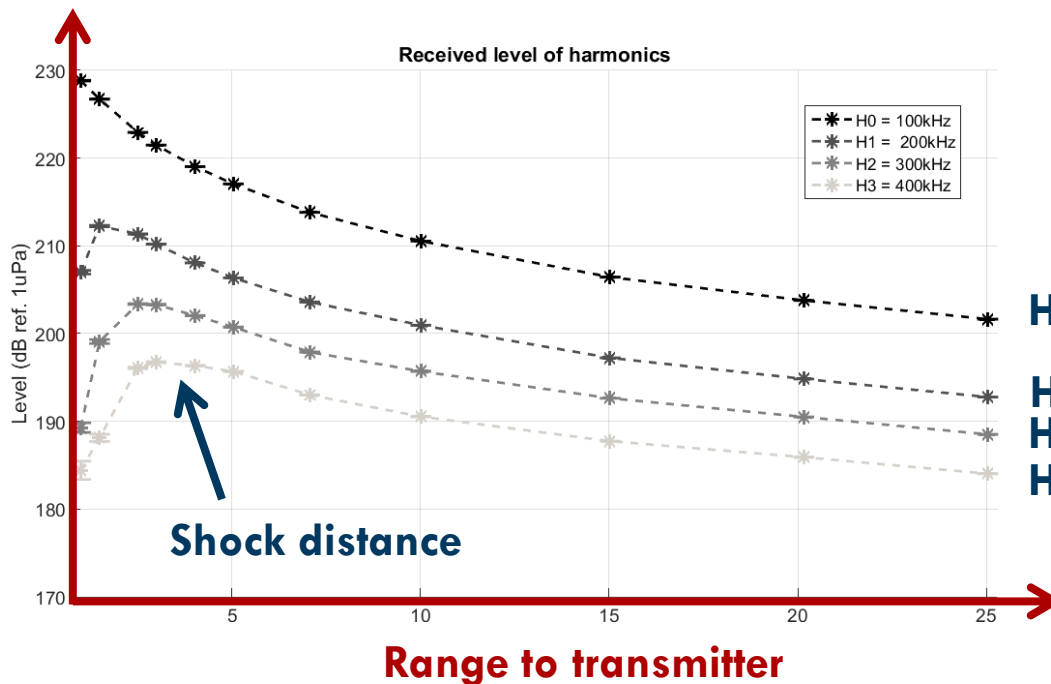


# Transmitter functional validation

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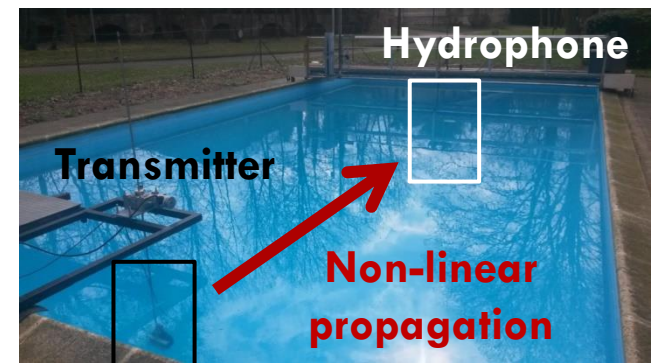
- Validation of harmonics creation : tank measurements at Sorbonne University – St Cyr (France)

## Harmonics levels (dB)



H0: Fundamental

H1  
H2  
H3



# Summary

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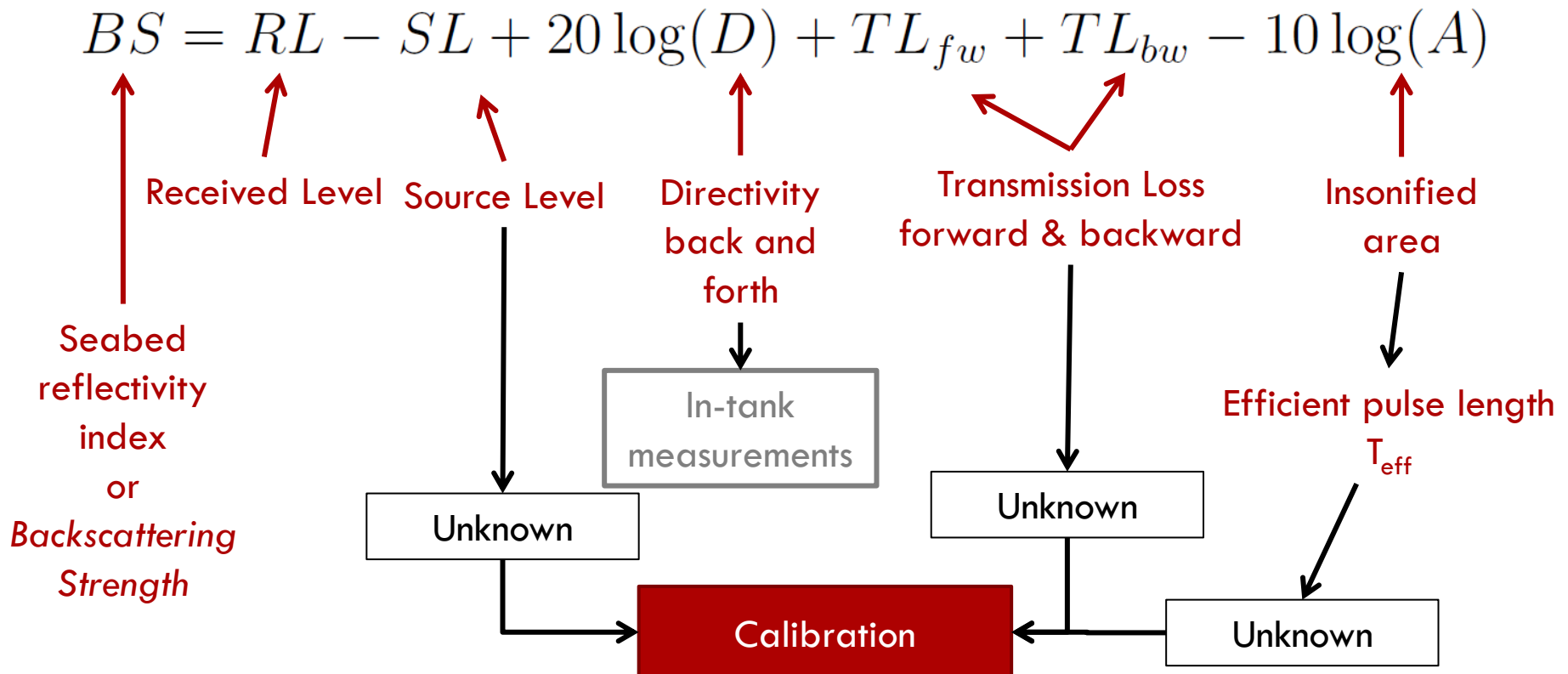


# Seabed reflectivity index calculation

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## □ Process:

### 1. Sonar equation

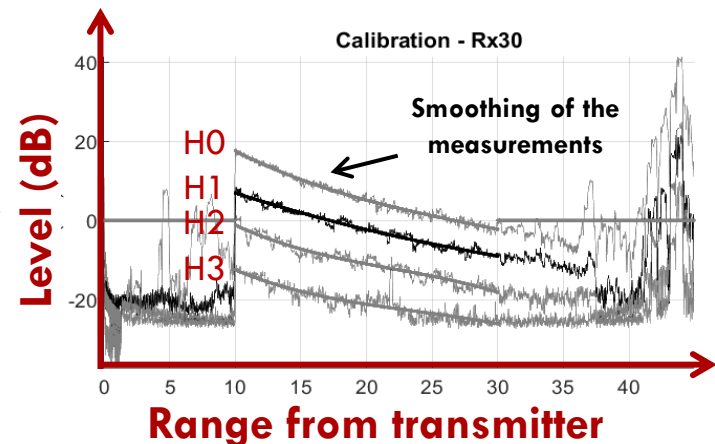
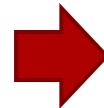
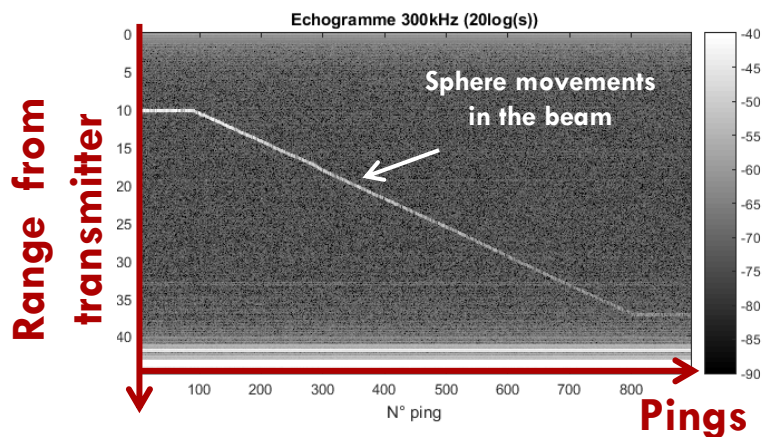


# Seabed reflectivity index calculation

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## □ Process:

1. Sonar equation
2. Calibration
  - Tungsten sphere which target strength  $TS(f)$  is perfectly known
  - Abacus of acoustic level at different ranges from the echosounder (10m to 30m).



# Seabed reflectivity index calculation

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## □ Process:

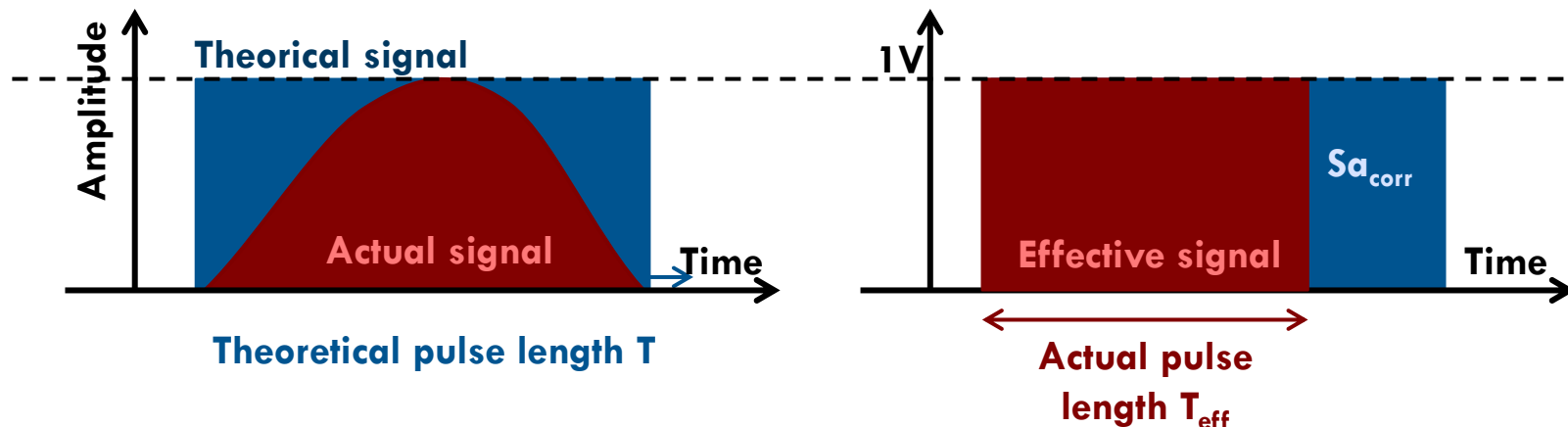
1. Sonar equation
2. Calibration
3. Calculation of  $T_{\text{eff}}$ 
  - Correction of effective energy transmitted:
  - Use of calibration data

Theoretical pulse length

Effective pulse length

$$10\log(T) = 10\log(T_{\text{eff}}) + Sa_{\text{corr}}$$

Backscatter calibration of high-frequency multibeam echosounder using a reference single-beam system, on natural seafloor.  
D. Eleftherakis et al, Marine Geophysical Research, 2018



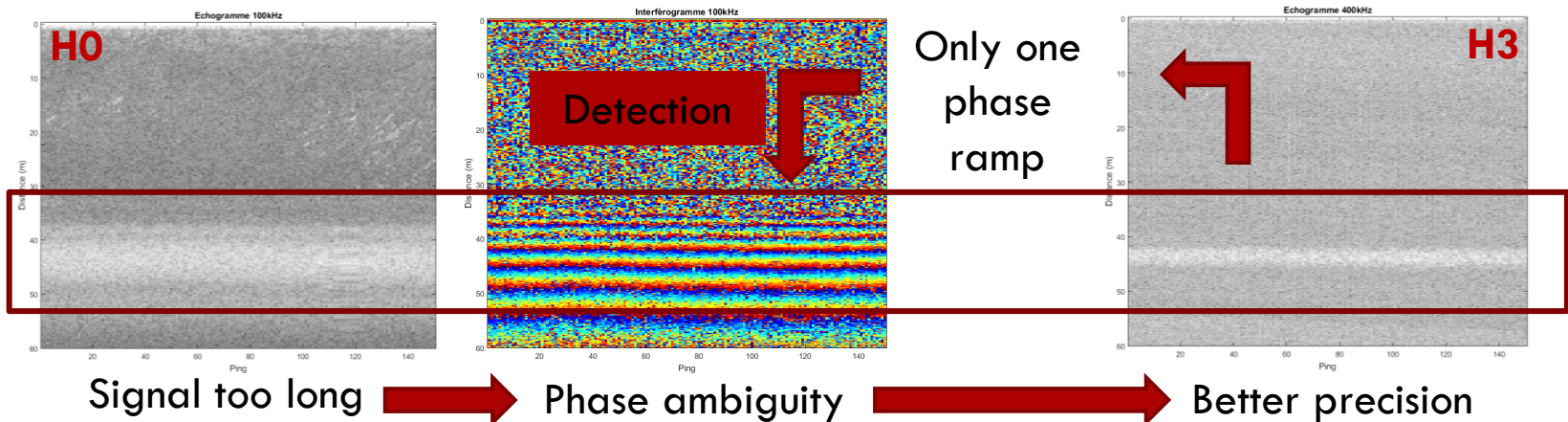
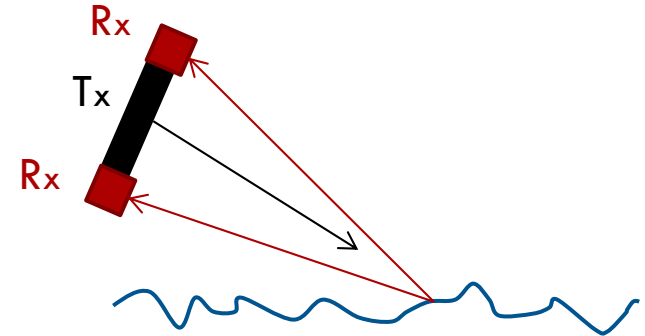
# Seabed reflectivity index calculation

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## □ Process:

1. Sonar equation
2. Calibration
3. Calculation of  $T_{\text{eff}}$
4. Seabed detection

- Use of amplitude and phase data at several frequencies



# Seabed reflectivity index calculation

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## □ Process:

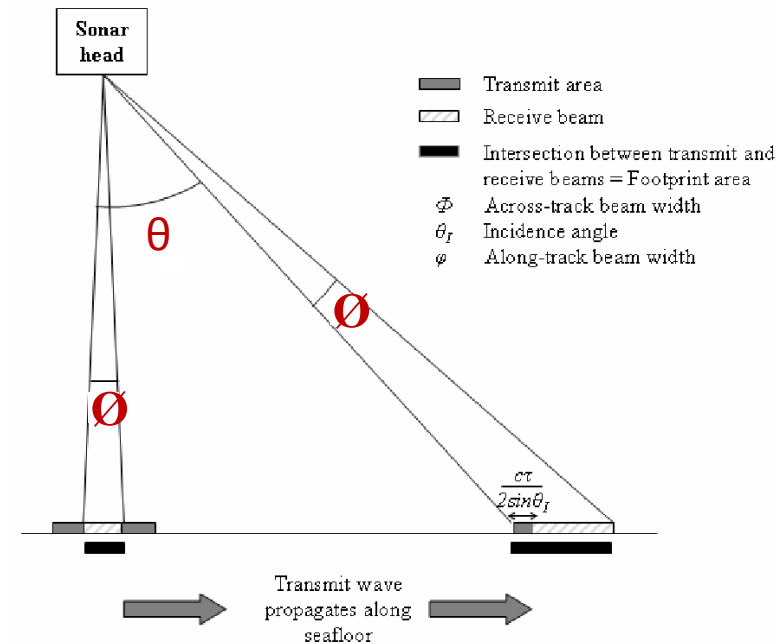
1. Sonar equation
2. Calibration
3. Calculation of  $T_{\text{eff}}$
4. Seabed detection
5. Insonified area calculation

- Classical insonified area formulae:

$$A_{th} = \min \left( (r \cdot 2\varnothing_{-3dB})^2, \frac{cT_{\text{eff}}}{2 \sin(\theta)} \cdot r \cdot 2\varnothing_{-3dB} \right)$$

Echosounder aperture

Incidence angle



I. Parum, Benthic habitat mapping using multibeam sonar systems, 2007

# Estimation and modelling of $BS(f, \theta)$

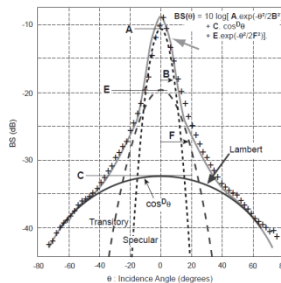
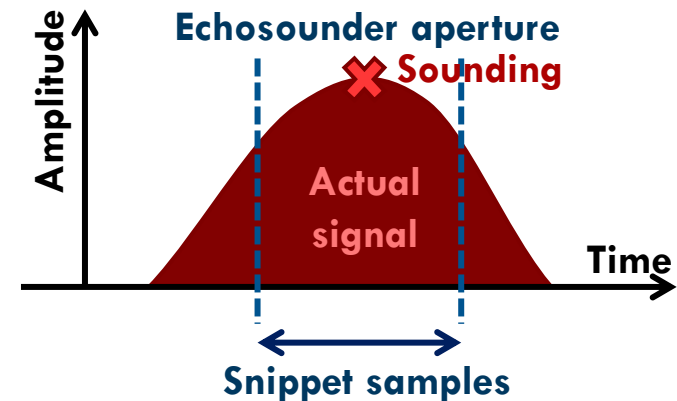
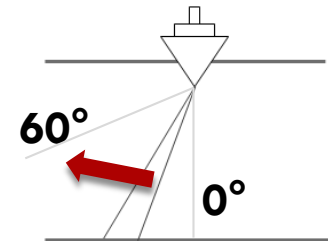
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## □ $BS(f, \theta)$ estimation:

- ▣ Mechanical movements of the echosounder
- ▣ For each angle: retaining intensity values around the detection inside the -3dB aperture (i.e. snippets).
- ▣ Mean of these values

## □ $BS(f, \theta)$ modelling

- ▣ GSAB model (X. Lurton)



$$BS(\theta) = \underbrace{A.exp(-\frac{\theta^2}{2B^2})}_{\text{Specular}} + \underbrace{C.cos^D(\theta)}_{\text{Grazing}} + \underbrace{E.exp(-\frac{\theta^2}{2F^2})}_{\text{Transitory}}$$

# Summary

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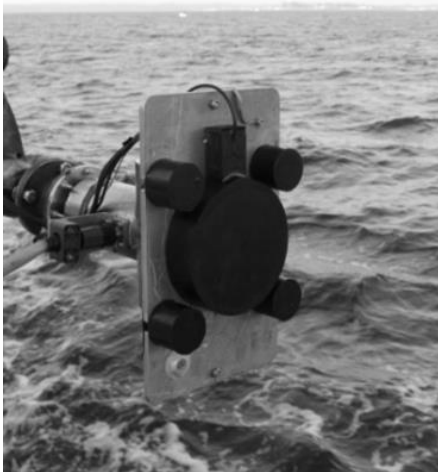
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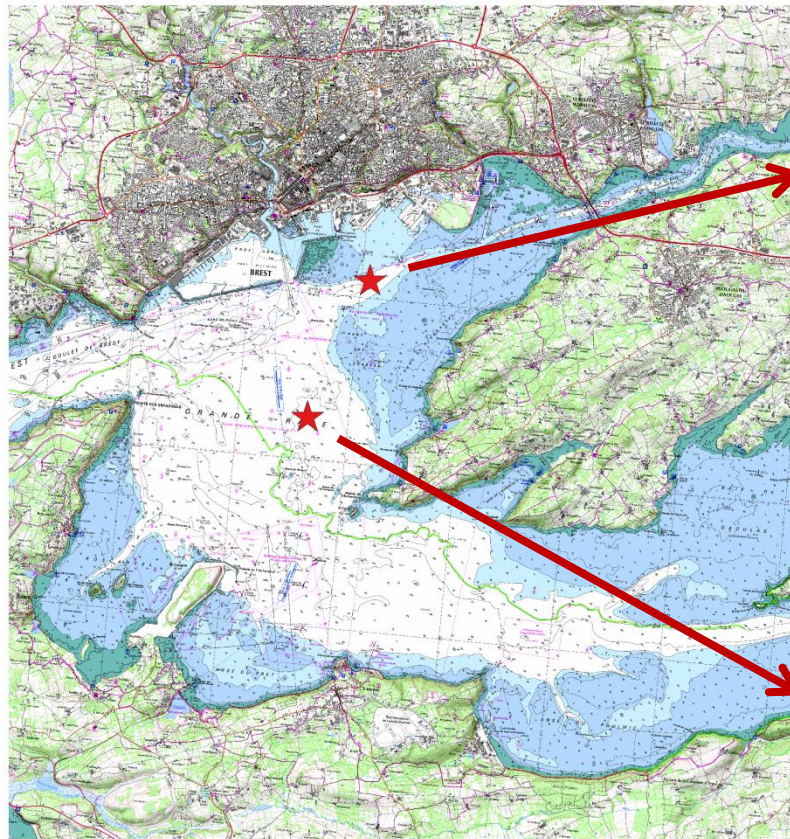
# Survey description

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- Thalia (Ifremer research vessel) in the bay of Brest



Echosounder fixed on a Pan&Tilt system, on a pool



**Sandy and soft seabed**

Mix of sand and mud that made dust clouds where the camera approaches – Dispersed small shells – Solitary starfish and some seaweed.

**Rough and hard seabed**

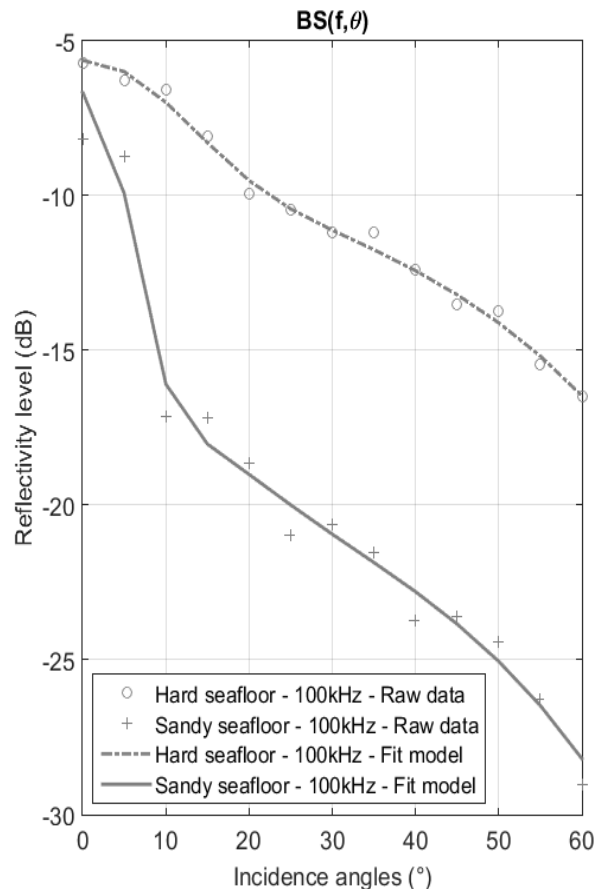
Hard seafloor with a lot of shells of different types – Rocks – Plenty of brittlestars.



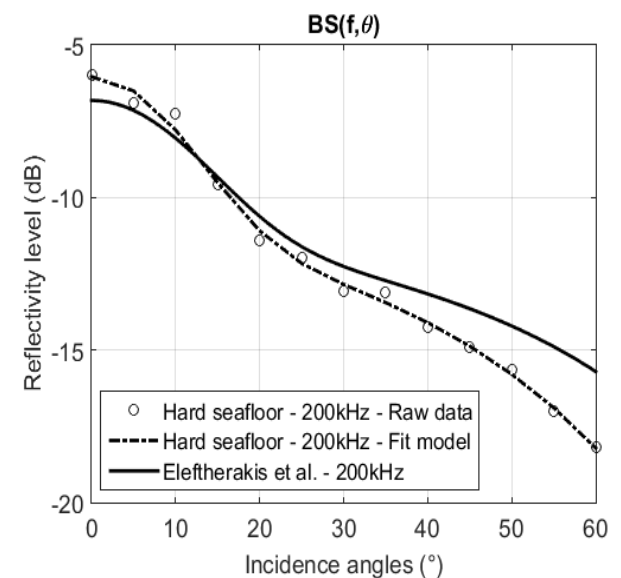
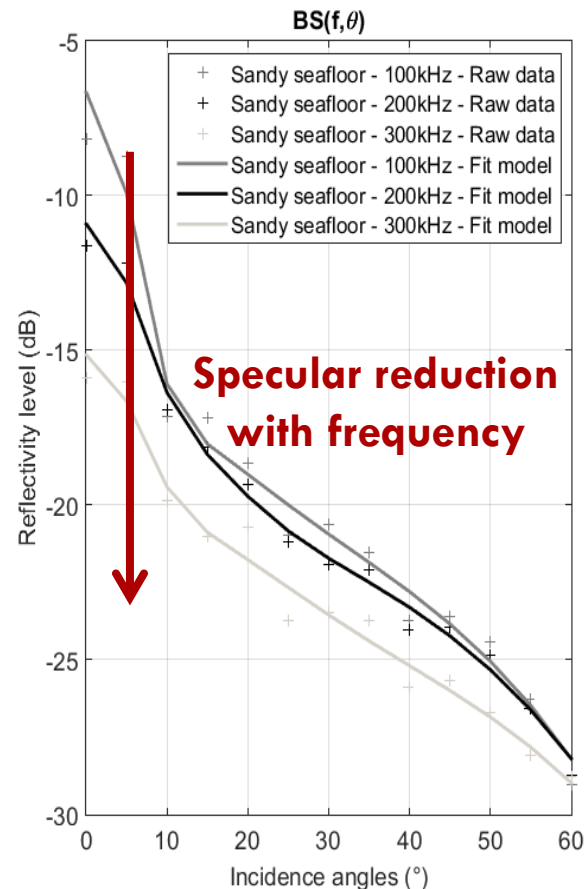
# Seafloor characterisation results

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## □ $BS(f, \theta)$ curves example



**Different seafloors  
= Different curves shapes**



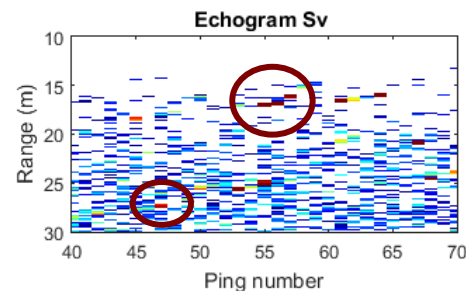
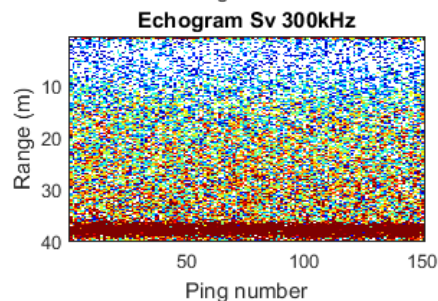
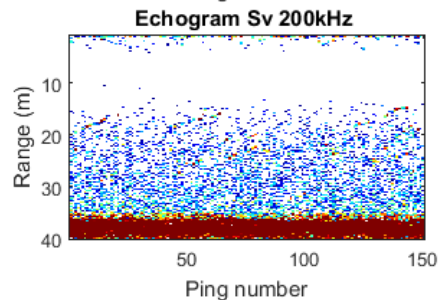
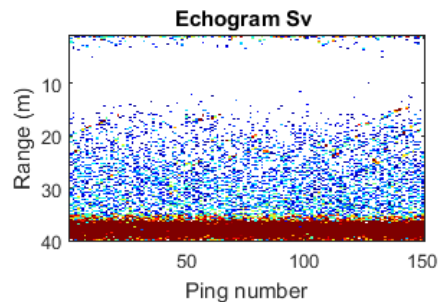
**Results close to Eleftherakis et al. calibration curve**

**Seafloor  
characterisation  
= Feasible solution**

# Application to fisheries acoustics

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## □ Example of echograms

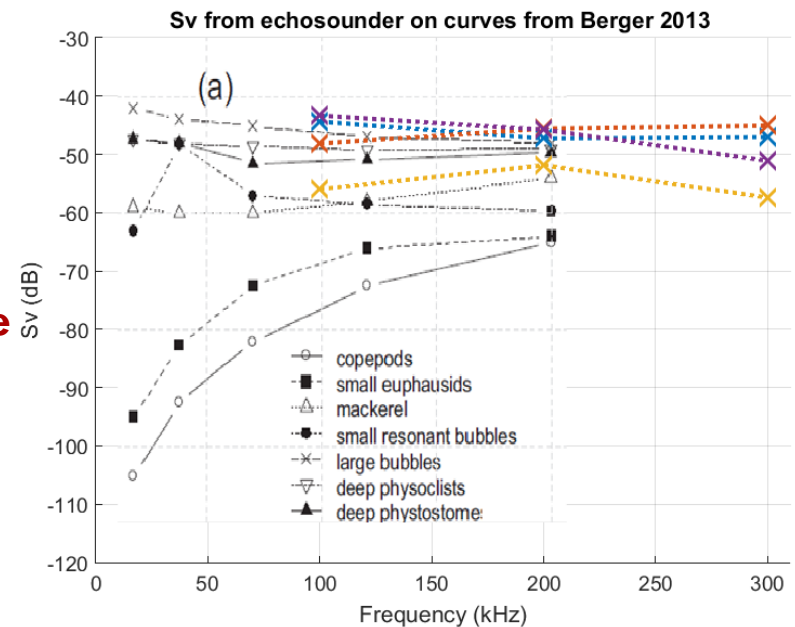


**Targets are observable**

**Perfectly  
in phase**



**Sv or Ts estimation = Feasible solution but better  
with a higher ping rate and sensitivity**



**Results in the order of magnitude of  
Berger et al. measurements**

# Conclusion and perspectives

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- Proof of concept of multifrequencies systems: ok
  - ▣ High level source and harmonic creation ✓
  - ▣ Wide band receivers ✓
  - ▣ In-tank processing chain calibration on sphere ✓
  - ▣ Relevant singlebeam echosounder results ✓
- Limitations
  - ▣ High transducer sensitivity to noise (ambient, vessel, ...) ✗
  - ▣ Mechanical tilt for several pointing angles ✗
- Perspectives
  - ▣ Use of lower frequencies and their harmonics (10-40kHz) for seafloor characterisation ?
  - ▣ Optimisation of rate and sensitivity for fisheries acoustics applications ?
  - ▣ MBES ?